NASA QUALITY REQUIREMENTS & COST CONTROL

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INTRODUCTION

NASA's space programs involve broad objectives for the scientific exploration of space and the development of competence in the associated technology. These programs are intended to establish the pre-eminence of this nation in space; thereby demonstrating our capacity for world leadership and the superior ability of American democracy to mobilize its scientific and industrial resources in response to today's needs. An up-to-date and detailed insight into the nature of our space programs and the technical and managerial problems involved in this vast effort of innovation and creativity can be found in the Proceedings of the Fourth National Conference on the Peaceful Uses of Space. (Ref. 1).

NASA's Quality Program is one of several technical disciplines necessary to the successful development and space flight operation of the small quantities of inherently costly research-type hardware through which man is conquering space. Reference (2) describes features of the Quality Program, including the application of Quality Publications, NPC 200-2 & 200-3, to NASA procurements.

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NATURE OF QUALITY REQUIREMENTS

To understand NASA quality requirements it is helpful to consider first that NPC 200-2 establishes broad, quality system requirements for space system contractors and that NPC 200-3 does the same for suppliers operating below the system level. The principles expressed in these Quality Publications:

- Encourage industry initiative in achieving quality and in developing objective evidence of quality.
- Permit use of those existing industry procedures found suitable for space quality, either as is, or with modifications.

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- Require deliberate management effort in many quality functions, including but not limited to traditional quality control and inspection.

- Permit variations in detailed effort to be tailored to the circumstances of individual procurements.

- Provide for a firm understanding of quality requirements prior to NASA purchase and definition of quality requirements in subsequent subcontracts.

- Require control from initiation of design through to operational use.

- Provide for early problem recognition and solution to avoid the cost and schedule impact of problem solutions delayed to the end-item test or launch site.

- Provide for personnel accountability and responsibility through identification of the worker with his work, training and certification.

These principles are intended primarily to help ensure mission success and flight crew safety. They offer identifiable opportunities for cost control in quality operations for NASA, both by suppliers and by the Research and Space Flight Centers exercising technical direction over NASA contracts. Both industry and NASA management need to provide skillful direction of quality efforts to achieve the required high reliability within justifiable and reasonable cost. The following facts must be recognized when relating the inherent features of planned quality programs to achieve space mission success with proper management of quality costs:

- The cost of failures in space missions is measured in tens and hundreds of millions of dollars.

- More important, the loss of even one astronaut in manned space flight is unacceptable.

In other words, quality effort to prevent failure is well worth its cost, since it offers almost unlimited potential for avoiding much higher and completely unacceptable costs in terms of missions and human lives.

MANAGEMENT RESTRAINTS

However, this does not mean that unlimited funds need be expended for quality or for reliability effort. NASA intends to achieve the highest quality and reliability within the necessary management restraints which apply to the entire space program. An insight into the many factors which must be weighed and balanced by management in every facet of space programs is contained in the following quotation from Dr. Robert Seamans, Jr., NASA's Associate Administrator, in his paper "Government and Industry" in reference (1):

"There are three variable factors that must be continuously considered in the management of our programs; namely, performance, cost, and time. It is possible to affect any one of these at the expense of the others. We make every effort to attain required performance within our budgetary authorization. We must take the time to conceive, design, build and test experiments of excellent quality and high value. We relax our target flight dates grudgingly, but we must recognize that success is measured in terms of the usefulness of the data received and that abortive flights provide little or no return and hence waste valuable resources."

QUALITY RELATED TO COST CONTROL

This paper will discuss some means whereby proper direction and implementation of quality system procedures can provide the necessary confidence of flightworthiness for launch vehicles and spacecraft while effectively managing quality costs.

NASA's approach to quality recognizes that providing the necessary degree of confidence in space flight hardware does cost more money than similar effort for either commercial or military weapons programs. However, costs are presently being incurred that are higher than necessary to achieve the required degree of confidence. This increment of cost can be removed by:

- Better management of quality assurance functions and practices.
- Applying quality assurance principles to the total job and relating their application to cost control.

The specifics for action may become evident by any of several means:

- Results of a quality survey by NASA or on-site Government agency acting for NASA.
- Results of supplier's audit of his own quality system (refer Section 15, NPC 200-2).
- Results of cost analysis or overhead survey by Government agency or by supplier's management.
- Industry self motivation to exercise initiative to improve its competitive position.

Regardless of the stimulus, experience indicates that higher quality can be consistently achieved by knowledgeable and skillful management of quality efforts and by application of quality assurance principles to the task at hand. At the same time, quality cost control should be agressively pursued by quality managers. Initiative, innovation and creation in the quality area of cost control will improve the quality position of both NASA contractors and NASA Centers within the previously mentioned management constraints.

CAUSES OF HIGH COSTS

Unreasonable, unnecessary, or unjustified quality costs on NASA contracts appear to arise mainly from:

a. A LACK OF UNDERSTANDING of NPC 200 series and other quality requirements. Visits to both primes and subs reveals that, although it is known that the 200 series requires careful reading and thoughtful application, requirements are sometimes either not read carefully enough for understanding or insufficient thought is given to applying a given requirement to the situation at hand. Understanding comes from face-to-face sessions between procuring NASA installations and its suppliers (prime and sub) and between the primes and the subs. (Note: Understanding is not direction; NASA directs subs only through the prime.)

A written quality system plan is a primary instrument to obtain understanding as follows:

- For the Government agency acting on behalf of NASA--a quality assurance plan is required, per NPC 200-1A.

- For the space system contractor (or major system subcontractor)--a quality program plan per NPC 200-2. Early understanding is facilitated by obtaining a preliminary plan with proposals and negotiating a detailed plan.

- For the supplier of materials, parts, components and services (below system level)--an inspection plan per NPC 200-3. Here, submittal is optional; the preparation and use of a plan is mandatory.

More attention to quality plans is needed to obtain the necessary understanding and at an earlier point in the development process.

b. <u>LACK OF SELECTIVITY IN APPLYING QUALITY REQUIREMENTS:</u>

- <u>At each level of procurement</u>. The system prime and the procuring NASA installation select quality requirements pertinent to a given purchase. A subcontractor does not need nor should he be asked to respond to every quality requirement; only to those that are applicable to the work or articles expected of him.

- <u>At each level of criticality</u>. This may be determined by the system designer using failure mode, effect, and criticality analysis in a formal way, or by previous flight experience, or sometimes by purely intuitive methods. It should be noted that complete simulation of all space environments and operating times in space is sometimes neither feasible nor practical.

- <u>At each level of environment</u>. Determining and defining expected space environments requires knowledge obtained from both contractor and NASA experience obtainable from the procuring NASA center and from scientific and technical reports. The latter may be found abstracted and indexed in STAR*

*STAR means Scientific & Technical Aerospace Reports, a comprehensive abstracting and indexing service published twice monthly. Inquiries regarding STAR should be directed to NASA, Office of Scientific and Technical Information, Washington, D.C. 20546.

c. <u>Lack of Trained Personnel For Source Inspections</u>. Well trained personnel (Government and contractor) having broad knowledge can transfer many preventive quality assurance actions to the scene of subcontractor operations, where these actions can be most effective and economic. Inept source inspection personnel are ineffective, and can generate delays and unnecessary costs without increasing quality.

NASA conducts numerous quality assurance training courses for its own personnel and those of other Government agencies who work on NASA contracts at supplier plants. Proper selection and training of source inspection personnel is considered an important cost control measure and a quality improvement factor.

It is important not to overlook the fact that ground support equipment may have extremely high reliability requirements, but GSE performance is achieved in the less hazardous environment of ground or ship stations. Some space flight equipment may operate normally in a benign environment within spacecraft (as within a manned spacecraft where conditions are controlled for astronaut life support), but must be able to operate even during a failure, such as loss of cabin atmosphere. Misapplication in either direction adversely affects both quality and cost.

TEST & INSPECTION PLANNING

On the positive side, better cost control and hard savings can be achieved by comprehensive test and inspection planning, knowing that space flight confidence requires large amounts of testing. This subject is treated in NPC 200-2, in NPC 250-1 and, for major systems, in integrated test plan requirements spelled out in contract work statements. It is recognized that many dollars go into various forms of testing, sometimes without considering the testing as part of quality assurance. Yet the requirements for the latter (refer Sections 4 & 7 of NPC 200-2) apply to all testing. Whether or not testing is treated as an activity per se, or as part of a Quality Program Plan, it is a large and costly endeavor in space programs; it merits the attention of managers, engineers, statisticians, quality assurance and reliability personnel. Features of test planning considering cost control should include:

- Accurate and timely total test program definition--related to all the articles and processes involved as well as end-use, criticality or effect on mission. Efficient use of test time with adequate testing involves merging technical requirements with cost and time considerations of the overall program.

- Avoidance of duplication--Test requirements arise from many performance and assurance requirements and by various organizational or operational segments. The decision to use available qualification data obtained from other programs and other suppliers is reserved by NASA (see par. 4.3 of NPC 200-2). However, the possibility of thereby reducing test costs needs to be pursued mindful of both high test costs in number of expensive samples (e.g. launch vehicles, spacecraft or major systems thereof), high facility costs to simulate space conditions and high test operating costs (e.g., to simulate solar radiation in large vacuum chambers may cost thousands of dollars per day).

- Enable multiple use of test setups, special test facilities and test programs. Quality engineers can arrange for multiple test operations at the time of design reviews and test design. Proper timing to permit multiple use can result from their participation in the early development phases.

- Extending design proof testing or qualification testing at anticipated system stress levels to overstress testing, including destructive testing, provides economy in the use of expensive samples. This should be time-phased to permit use of early test results to determine ultimate qualification test levels and number of samples.

- Adjusting and revising test programs and test and inspection procedures to utilize incremental knowledge gained by each flight. This includes re-examination of ground test objectives and detailed procedures in the light of operations in space and as the result of pre-launch troubles and launch holds. Some program managers consider this a continuous task.

- Better records and associating specific test results with particular pieces of hardware. This requires a realistic determination of documentation requirements so that desired and useful data is not only retained, but is available to the test planner and is used to guide the test program.

Without good records, adjustment of test programs or multiple use of tests is impossible.

- Proper appreciation for expected operating life will influence both the amount of testing and stress levels for components expected to be flown, each having its impact on quality confidence and dollars. Obviously an efficient program will provide necessary preflight confidence with a maximum of useful life remaining in flight articles. This factor alone can justify an integrated test program.

- Consideration of storage life, for intervals involved in ultimate assembly, test, checkout and launch of space systems as well as requirements for storage in the space environment and subsequent activation in space. The continued validity of test results to determine flight worthiness is of prime concern; however, if the results of storage can invalidate test results for such a conclusion, the testing and the sequence of testing should be judiciously selected. Some seals and materials subject to corrosion require replacement after ground test or storage, and prior to space flight; necessary revalidation and retest required at the launch site should influence duration of previous tests in such cases.

Symptoms of poor test planning include test failures excused away as test error, personnel error, test set-up error; inadequate test procedures, inadequate safety measures for both personnel and equipment involved; lack of test criteria; and insufficient or improperly selected test equipment. All of these factors are effectively treated in a good Quality Program.

APPLYING QUALITY DATA

Specific applications of NASA quality assurance to cost control can result from using quality data as required by Section 14 of NPC 200-2, particularly when applied early in the procurement-to-use cycle. Quality data should be used and fulfill a purpose; otherwise it should not be collected. Presentation of quality data should be geared to serve the user of the data, to facilitate applying experience to current design, application and selection of articles as well as to revise or strengthen quality control effort. Improved quality at less cost can result from rapid use of data, better selection of which data is to be recorded

(particularly variables data which is more costly to obtain, but also more useful) and a greater penetration of quality data into all operations affecting cost. For example, selected variables data on calibration intervals and instrument deviations should be used in purchasing test equipment as well as to revise the frequency of calibrations.

Failure and malfunction data from all inspection and test operations should quickly reach outside suppliers, designers and fabricators and also the quality control personnel immediately involved. Whether or not the volume of data justifies automated processing, procedures should be designed to facilitate response to such data, thereby reducing cost while improving quality.

For example, the coding used in a corrective action reporting system (refer par. 14.3 of NPC 200-2) can be designed to identify quickly the failure mode, the cause of failure and the corrective action in the language applicable to a class of articles (e.g., gyro, transducer, or actuator) in lieu of using a standardized coding designed for all articles. Malfunction data expressed in the language of the user will be used as intended. Personnel who report or analyze failures will not waste effort in trying to fit their unique experience to a standard situation--a frustration which can defeat a costly and elaborate corrective action system.

If data is timely, pertinent and presented in a manner to facilitate rapid use, it will be used and savings from application of experience will accrue without need for authoritarian direction to the people concerned. Furthermore, good data reporting can also be designed to alert top management (technical and nontechnical) on whether closed-loop corrective action has resulted and whether such action is adequate. Both mission success and cost control are greatly enhanced by designing corrective action data systems for decision-making focused on preventing future failures.

PRACTICAL RECORDS MANAGEMENT

A practical cost control idea is the timely determination of which quality data is to be provided with the hardware delivered to the test or launch site, and which data is to be retained by the lower-tier supplier for analysis and use upon request. Data needed for launch or test site operations should be provided in the form and amount appropriate to its use. Reference data can be economically retained and retrieved by either manual or automated methods, depending upon the volume and frequency of use.

When selecting data to inform management of quality status, consider both the kinds of decisions to be made at that particular management level and the impact that an informed management can have in motivating operating personnel. Quality data should be used both for decision making (e.g. test program, acceptance, flight worthiness) and for measuring how well the quality program is functioning.

METROLOGY

Metrology costs are greatly affected by the ability to relate calibration intervals to required precision and periods of actual use. Calibrating too frequently increases the quantity of instruments and test equipment to be purchased and maintained. Proper management of the metrology function can result in dollar savings with appropriate precision. Economy comes from operating this function on a plant or institutional basis serving all projects within a plant. Unnecessary duplication of calibration standards increases cost; long calibration chains reduce maintenance of accuracy. Instruments not in active use should be removed from operating areas to permit valid extension of calibration intervals and avoid damage and resulting repairs.

FUNCTIONAL ASSIGNMENT OF TASKS

Attention is invited to applying normal management improvements that are not necessarily peculiar to quality operations. Reducing excessive layers of supervisory personnel produces hard savings and better work control. This has been demonstrated in both Government and industry quality control and inspection operations. Duplication of functions increases costs, makes improper use of personnel skills and lowers morale. Specific assignment of quality responsibility and extent of functional performance will eliminate any duplication caused by the possible overlap of quality and reliability operations.

To avoid duplication of reliability and quality effort, authority or responsibility, apply Appendix E of NPC 250-1 as a starter, and mix a knowledge of the most economical place for every required function with a knowledge of existing practices and recent hardware experience. Both NPC 200-2 and NPC 250-1 emphasize function and basic requirements without regard to organizational nomenclature or mandatory supplier organizations. NPC 200-2 also requires that fabrication and inspection operations be identified with the personnel responsible, thereby setting the stage for motivating personnel.

MOTIVATION

Before closing on the theme of NASA quality requirements and associated cost control, it is well to observe that all of the above involves action resulting from management direction in response to contract requirements. In addition, to achieve the necessary high quality at a cost within reasonable budgets requires personnel to be not only trained but motivated. The value of motivation is high since it contributes much to high quality at small cost. The PERSHING program is reported to be the first to conclude that quality can be improved only so far by management direction; motivation should provide the rest (see reference 3).

NASA endorses contractor-developed plant-wide motivation programs. These may operate under various names (e.g. Zero Defects, Do Good Work, PRIDE and VIP). Motivation programs can be enhanced by use of the tremendous stimulus of the space challenge.

▶ This route to quality recognizes that:

- motivated people can achieve the highest standards set by management,
- people can be motivated by recognition of the importance of their work and its contribution to the space program, which is exciting, difficult, and significantly involves our national resources.

Information, motion pictures,* (such as "Manned Space Flight, 1964" shown here this morning) and other ideas can be obtained by contacting the procuring NASA installation. For manned space flight, there is a Manned Space Flight Awareness Program, which formally generates motivation effort, including visits of astronauts to plants, making personal contacts with the people producing space hardware. The value of motivation efforts to improve quality was amply demonstrated in the MERCURY program, whose success has been attributed in great part to proper motivation of the many people involved.

* A list of NASA films and sources can be obtained from NASA Headquarters, Code AFEE-3, Washington, D.C. 20546.

The "Do Good Work" program, developed by General Dynamics Astronautics, was suggested by Astronaut Virgil Grissom's oft repeated "do good work" request to all persons concerned with the Atlas booster so successfully employed in Project MERCURY. This motivation program makes use of quality data to indicate quality improvement in current space work.

SUMMARY

In summary, quality achievement and quality cost control can be enhanced by applying good management to quality effort and by relevant application of NASA quality assurance principles. Both quality achievement and quality cost control are ingredients of space program success, and thereby are building blocks to national achievement of pre-eminence in space. Professional skills should be focused on both subjects in order that this nation may enjoy the fullest benefits of space leadership.

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